

(19) World Intellectual Property
Organization
International Bureau



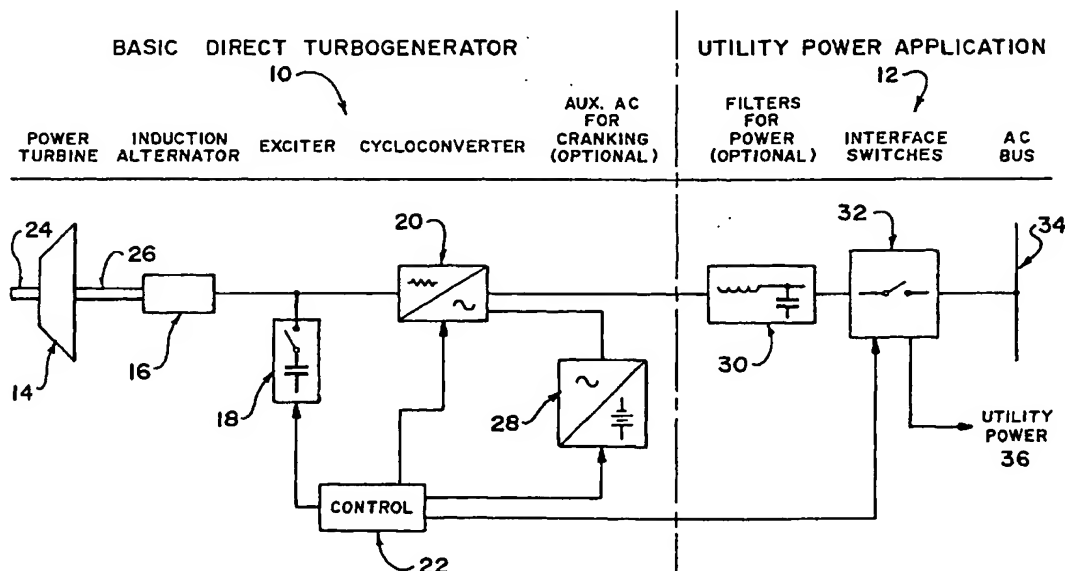
(43) International Publication Date
21 May 2004 (21.05.2004)

PCT

(10) International Publication Number
WO 2004/042890 A1

- (51) International Patent Classification⁷: **H02J 3/38**, (81) Designated States (*national*): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE, EG, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK (utility model), SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (21) International Application Number: PCT/CA2003/001708
- (22) International Filing Date: 5 November 2003 (05.11.2003)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data: 2,411,132 5 November 2002 (05.11.2002) CA
- (71) Applicant (*for all designated States except US*): **RAILPOWER TECHNOLOGIES CORP.** [CA/CA]; 202-50 Fell Avenue, North Vancouver, British Columbia V7P 3S2 (CA).
- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): **DONNELLY, Frank, Wegner** [US/CA]; 509 East 6th Street, North Vancouver, British Columbia V7J 2Z2 (CA).
- (74) Agent: **GREEN, Bruce, M.**; Oyen Wiggs Green & Mutala, #480-601 West Cordova Street, Vancouver, British Columbia V6B 1G1 (CA).
- (84) Designated States (*regional*): ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:
- with international search report
 - before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: DIRECT TURBOGENERATOR



(57) Abstract: A transformerless direct turbogenerator for generating electricity is provided. Since the introduction alternator comprises multiple parallel windings, it allows elimination of the need for a transformer.

Direct Turbogenerator

Technical Field

- 5 [0001] The invention relates to the field of power turbines used for power generation, and more particularly turbogenerators for generating electricity which use a cycloconverter.

Background

10

[0002] Gas turbines, either derived from aeroplane or industrial applications have been used and are being increasingly used to generate electrical power. Previously gas turbine power generation systems have used synchronous generators. In such systems, the gas turbine is connected to a gearbox to reduce the speed and then attached to a synchronous alternator. In recent times it has also been known to attach a high-speed alternator to produce rectified DC current and then produce usable AC by attaching an inverter.

15

20

[0003] The use of synchronous generators with a gas turbine to generate electric power has some disadvantages in that to maintain a constant frequency of the output either the speed of the generator must be kept constant or a frequency changer is required to convert the synchronous generator signal to an output signal with a precisely regulated frequency. It has been known to use an induction generator in place of a synchronous generator, with a signal handling circuit such as a frequency changer or cycloconverter to provide an output signal having a desired frequency and amplitude. See United States Patent no. 3,832,625 Gyugi. Cycloconverters are used to convert AC power at a fixed frequency to AC power at a lower frequency. In such systems a transformer is generally required between the cycloconverter and the alternator or between the cycloconverter and the output. Such an arrangement requires a larger volume for the generator, and greater cost.

25

30

[0004] There is therefore a need for a transformerless turbogenerator.

Summary of the Preferred Embodiment

35

[0005] This invention provides a new type of turbogenerator that is more direct and thus more efficient with a lower capital cost. The direct cycloconverter also

- 2 -

eliminates the need for a gearbox but has the added advantage of avoiding the need for a DC link.

[0006] The present invention therefore provides a turbogenerator having:

- 5 a) a turbine prime mover,
- b) an induction alternator,
- 10 c) an excitation system for the induction alternator comprising a plurality of static capacitors and switches,
- d) a cycloconverter connected to the induction alternator, and
- 15 e) a control circuit to control the excitation system and cycloconverter.

Brief Description of Drawings

[0007] In drawings which illustrate a preferred embodiment of the invention:

20 Fig. 1 is a simplified schematic drawing of the direct turbogenerator of the invention connected to a utility power grid; and

25 Fig. 2 is a circuit diagram illustrating a preferred form of transformerless cycloconverter for use with the invention.

Description

[0008] Throughout the following description, specific details are set forth in order
30 to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

35

- 3 -

[0009] With reference to Fig. 1, the basic direct turbogenerator of the invention is designated as 10 with an adaptation 12 for connection to a utility power system. The direct turbogenerator 10 includes a power turbine 14, an induction alternator 16, exciter 18, cycloconverter 20 and control 22. It may also have an auxiliary source of AC power 28 (Fig. 2) for starting the gas turbine.

[0010] Power turbine 14, shown schematically in Fig. 1 on shaft 24 and having power shaft 26, is part of a gas turbine engine, the remaining parts, primarily the compressor and combustor, not being shown. The gas turbine of which power turbine 14 is a part will preferably be a micro-turbine, mini-turbine, or small gas turbine, having a power output in the general range of 25 kilowatts to 20 megawatts. Any type of gas turbine engine, whether simple cycle, recuperated or intercooled and recuperated may be used. The power turbine may be connected by shaft 24 to the compressor, as in a single spool gas turbine engine, or it may be on a separate shaft from the compressor, as in a double spool gas turbine engine. If a single spool gas turbine is used, an auxiliary AC power source may be provided in connection with the cycloconverter 20 to crank the shaft 26 to start the gas turbine.

[0011] Induction alternator 16 is coupled to power turbine 14 either directly by shaft 26 or through a gearbox (not shown). It is excited by exciter 18 which is a plurality of static capacitors and switches. Exciter 18 is controlled by controller 22, which may be for example a Programmable Logic Controller.

[0012] Where the turbogenerator is to be interfaced to a utility power system 36, filters 30 can be connected to the output. These may be smoothing reactor or LC filters. Interface switches 32 may also be connected, controlled by controller 22, to isolate the circuit from the utility grid in the event of outage surges, ground faults and the like. The output power is connected to AC Bus 34, to utility power 36 or both AC Bus 34 and utility power 36.

[0013] Figure 2 is a circuit diagram illustrating the preferred circuit of the invention. Induction alternator 16 has three individual phase windings 41, 43, 44. Excitation is provided by a plurality of capacitors 45 and switches 47 arrayed around the stator 40. The switch/capacitor arrangement around the induction alternator stator 40 provides the necessary reactive power for the excitation of the alternator as well as a means of counteracting the effects of phase control current from the naturally

- 4 -

commutated cycloconverter. This is an improvement over the past approaches where naturally commutated cycloconverters were connected to a synchronous alternator that supplied current with significant displacement from their internally produced voltages. This results in lower losses, higher efficiency and desired sizing and capital costs are achieved with this approach. Since the induction alternator comprises multiple parallel windings it allows elimination of the transformer

[0014] Cycloconverter 20 comprises a plurality of switches 50, preferably six. These may be silicon controlled rectifiers. Where an independent alternating current power source 28 back feeds the cycloconverter, it can be used to start the prime mover using the induction alternator.

[0015] The invention therefore provides in a preferred embodiment a transformerless turbogenerator comprising: a) a turbine prime mover; b) an induction alternator comprising a plurality of parallel windings; c) an excitation system for the induction alternator comprising a plurality of static capacitors and switches; d) a naturally commutated cycloconverter connected to the induction alternator, and e) a control circuit to control the excitation system and the cycloconverter.

[0016] As will be apparent from the foregoing, this invention has uses for both the production of electrical power at commercial power frequencies and driving of motors in applications such locomotives, ships and other vehicle applications.

[0017] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.

- 5 -

WHAT IS CLAIMED IS:

1. A turbogenerator comprising:
 - 5 a) a turbine prime mover;
 - b) an induction alternator;
 - 10 c) an excitation system for said induction alternator comprising a plurality of static capacitors and switches;
 - d) a cycloconverter connected to said induction alternator, and
 - 15 e) a control circuit to control said excitation system and said cycloconverter
2. The turbogenerator of claim 1 wherein said induction alternator comprises a plurality of parallel windings thereby allowing elimination of a transformer.
- 20 3. The turbogenerator of claim 2 wherein said induction alternator comprises three parallel windings.
4. The turbogenerator of claim 1 further comprising an independent alternating current power source in circuit with said cycloconverter to permit starting of the
25 prime mover using the induction alternator.
5. The turbogenerator of claim 1 wherein said cycloconverter is naturally commutated.
- 30 6. The turbogenerator of claim 5 wherein said cycloconverter comprises a plurality of switches.
7. The turbogenerator of claim 6 wherein said cycloconverter comprises a
35 plurality of silicon controlled rectifiers.

- 6 -

8. The turbogenerator of claim 1 wherein said controller is a programmable logic controller.

9. A transformerless turbogenerator comprising:

5

a) a turbine prime mover;

b) an induction alternator comprising a plurality of parallel windings;

10

c) an excitation system for said induction alternator comprising a plurality of static capacitors and switches;

d) a naturally commutated cycloconverter connected to said induction alternator, and

15

e) a control circuit to control said excitation system and said cycloconverter

10. The turbogenerator of claim 9 further comprising an independent alternating current power source in circuit with said cycloconverter to permit starting of the prime mover using the induction alternator.

20

11. The turbogenerator of claim 9 wherein said induction alternator comprises three parallel windings.

25

12. The turbogenerator of claim 9 wherein said cycloconverter comprises a plurality of switches.

13.. The turbogenerator of claim 12 wherein said cycloconverter comprises a plurality of silicon controlled rectifiers.

30

14. The turbogenerator of claim 9 wherein said controller is a programmable logic controller.

35

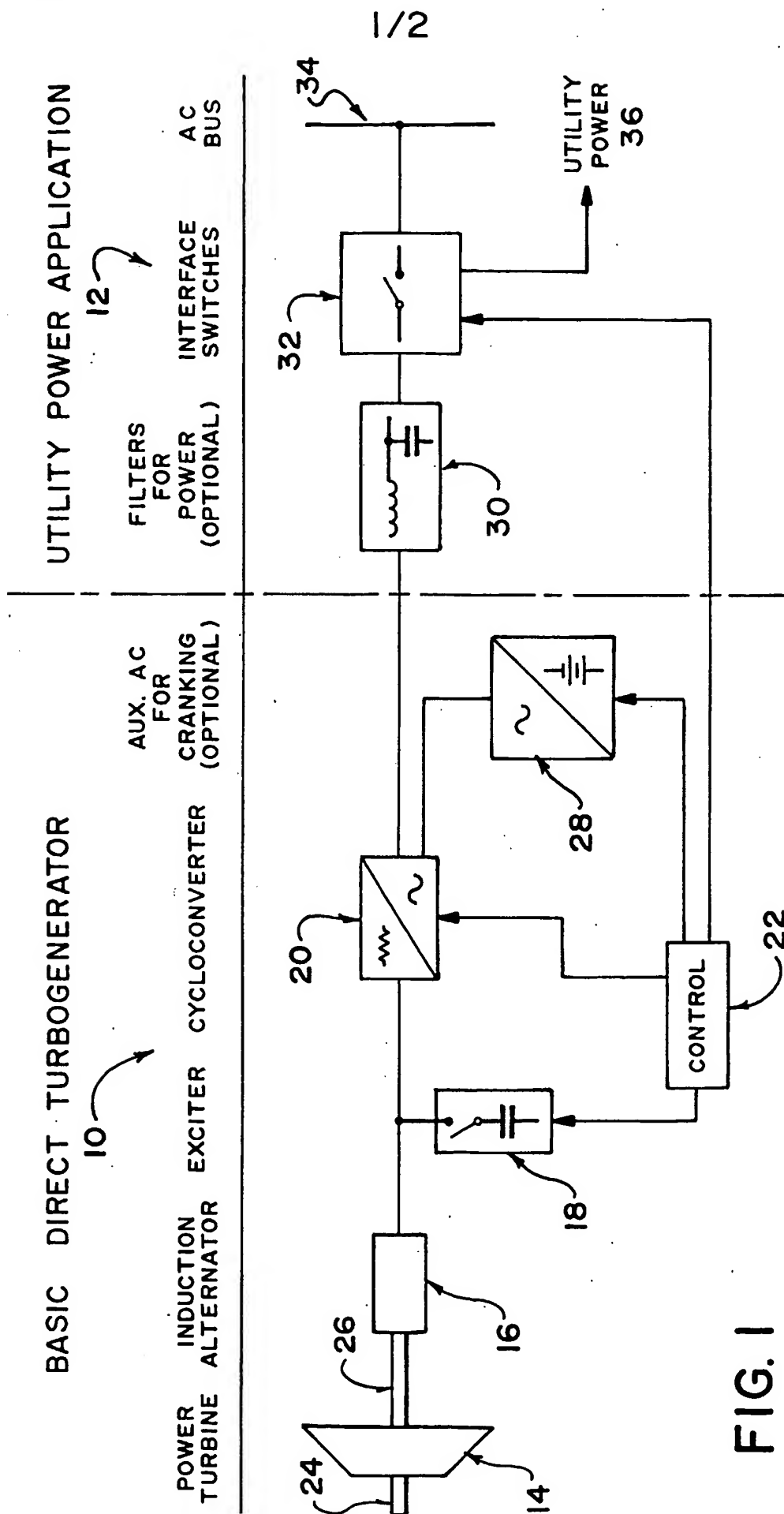


FIG. 1

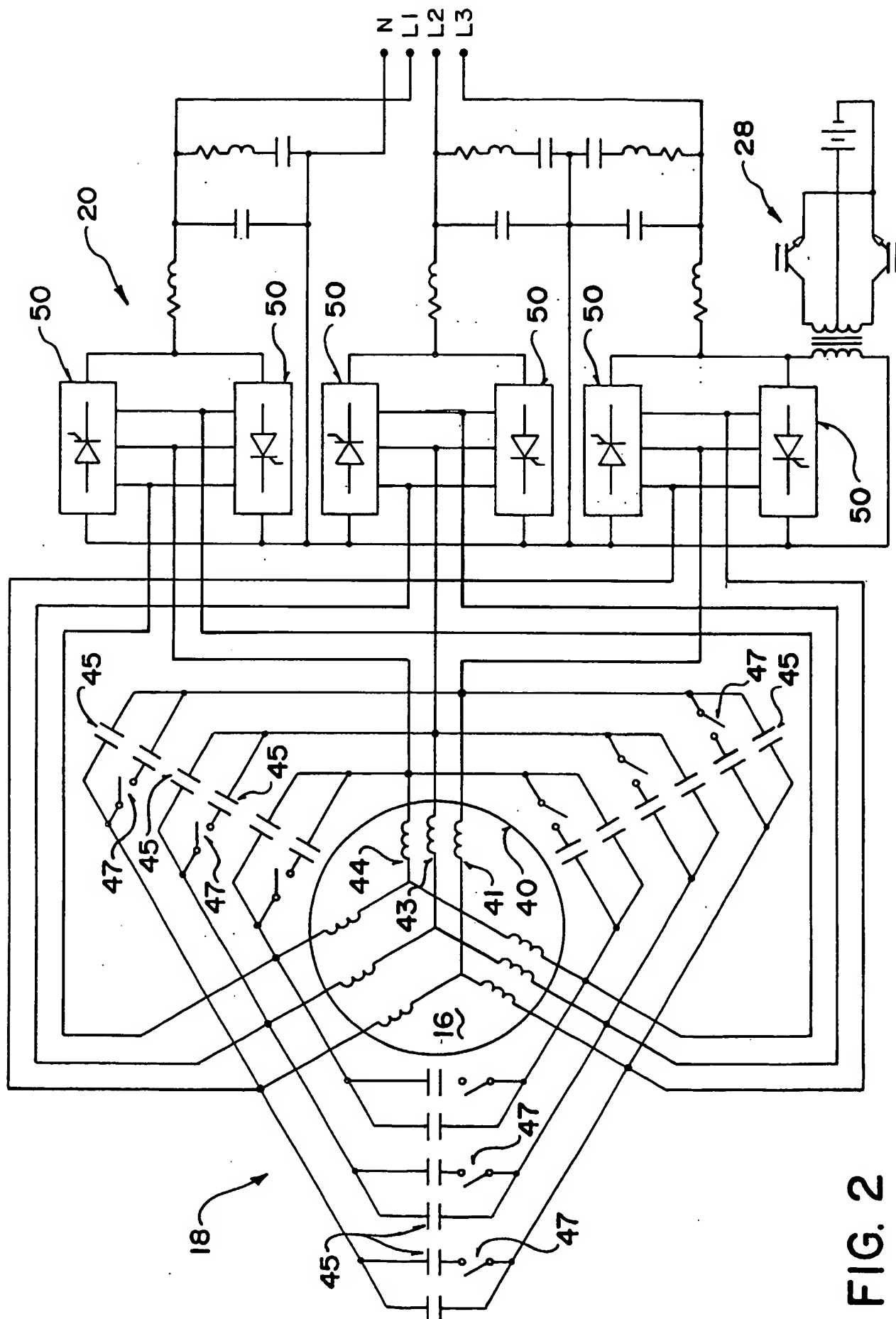


FIG. 2

A. CLASSIFICATION OF SUBJECT MATTER IPC 7 H02J3/38 H02M5/27 F01D15/10 H02P9/46		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 7 H02J H02M F01D H02P		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data, PAJ		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3 832 625 A (GYUGYI L) 27 August 1974 (1974-08-27) cited in the application column 3, line 3 - line 62 column 5, line 15 - line 22; figure 2 ---	1-14
Y	US 4 417 194 A (CURTISS WILLIAM P ET AL) 22 November 1983 (1983-11-22) column 7, line 58 - column 8, line 58; figures 1,2 ---	1-14
A	EP 0 348 938 A (LOHER AG) 3 January 1990 (1990-01-03) abstract; figure 2 -----	1-14
<div style="display: flex; justify-content: space-between;"> <input type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex. </div>		
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>* Special categories of cited documents :</p> <p>*A* document defining the general state of the art which is not considered to be of particular relevance</p> <p>*E* earlier document but published on or after the international filing date</p> <p>*L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>*O* document referring to an oral disclosure, use, exhibition or other means</p> <p>*P* document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>*&* document member of the same patent family</p> </div> </div>		
Date of the actual completion of the international search <div style="text-align: center; font-weight: bold;">5 March 2004</div>		Date of mailing of the international search report <div style="text-align: center; font-weight: bold;">15/03/2004</div>
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer <div style="text-align: center; font-weight: bold;">Gentili, L</div>

BEST AVAILABLE COPY

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 3832625	A	27-08-1974	JP 999499 C	30-05-1980
			JP 50018916 A	27-02-1975
			JP 54035284 B	01-11-1979
US 4417194	A	22-11-1983	CA 1169486 A1	19-06-1984
			CA 1181482 A2	22-01-1985
			CA 1181483 A2	22-01-1985
			DE 3113178 A1	06-05-1982
			ES 8302377 A1	01-04-1983
			ES 8305974 A1	16-07-1983
			ES 8305975 A1	16-07-1983
			ES 8305976 A1	16-07-1983
			ES 8305977 A1	16-07-1983
			ES 8306933 A1	16-09-1983
			ES 8305978 A1	16-07-1983
			ES 8305979 A1	16-07-1983
			ES 8305980 A1	16-07-1983
			ES 8305981 A1	16-07-1983
			FR 2490421 A1	19-03-1982
			GB 2085622 A , B	28-04-1982
			GB 2141885 A , B	03-01-1985
			GB 2141886 A , B	03-01-1985
			GB 2142450 A , B	16-01-1985
			GB 2142451 A , B	16-01-1985
			GB 2142491 A , B	16-01-1985
			IT 1143472 B	22-10-1986
			JP 57116600 A	20-07-1982
EP 0348938	A	03-01-1990	DE 3833719 C1	19-10-1989
			DE 58904600 D1	15-07-1993
			DK 327389 A	02-01-1990
			EP 0348938 A1	03-01-1990

BEST AVAILABLE COPY